Conception and Engineering of Cropping Systems: How to integrate ecological approaches ?

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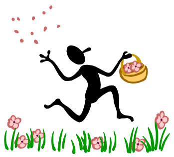
Ur HortSys Ur AIDA

Symposium international sur l'agroécologie pour la sécurité alimentaire et la nutrition
18-19 septembre 2014, FAO - Rome

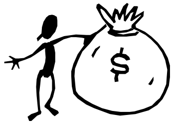
Global challenges

- **Challenges for food**
  - Feeding 6 to 9 billions people in 2050
  - In an increasingly urban context, scarcity of resources and climate change




- **Challenges for health**
  - Interactions between food systems and health and nutrition
  - Positive: micronutrients, diet
  - Negative: chemical residues from pesticides in the products


- **Economical and social challenges**



- **Environmental challenges**
  - Maintaining water quality
  - Conservation of soils
  - Climate mitigation, fossile energy preservation
  - Biodiversity conservation
  - Ecosystem health


Global challenges

Specialization and intensification (through chemical industry) have induced major environmental impacts (soils, water, climate, biodiversity) both in northern and southern agricultures

A great challenge for agronomists and scientists

- Objective: Achieve a sufficient production (quantity and quality) to satisfy:
  - An increasing and changing demand at a world scale
  - The economic profitability and social development for farmers
  - And, in the same time, preservation of the environment and <u>limitation of risks</u> for humans and ecosystems

- **A main question: Which cropping systems to address these different objectives ?**

T Doré, D Makowski, E Malézieux, N Munier-Jolain, M Tchamitchian, P. Tittonell
Facing up to the paradigm of ecological intensification in agronomy: Revisiting methods,concepts and knowledge - 2011

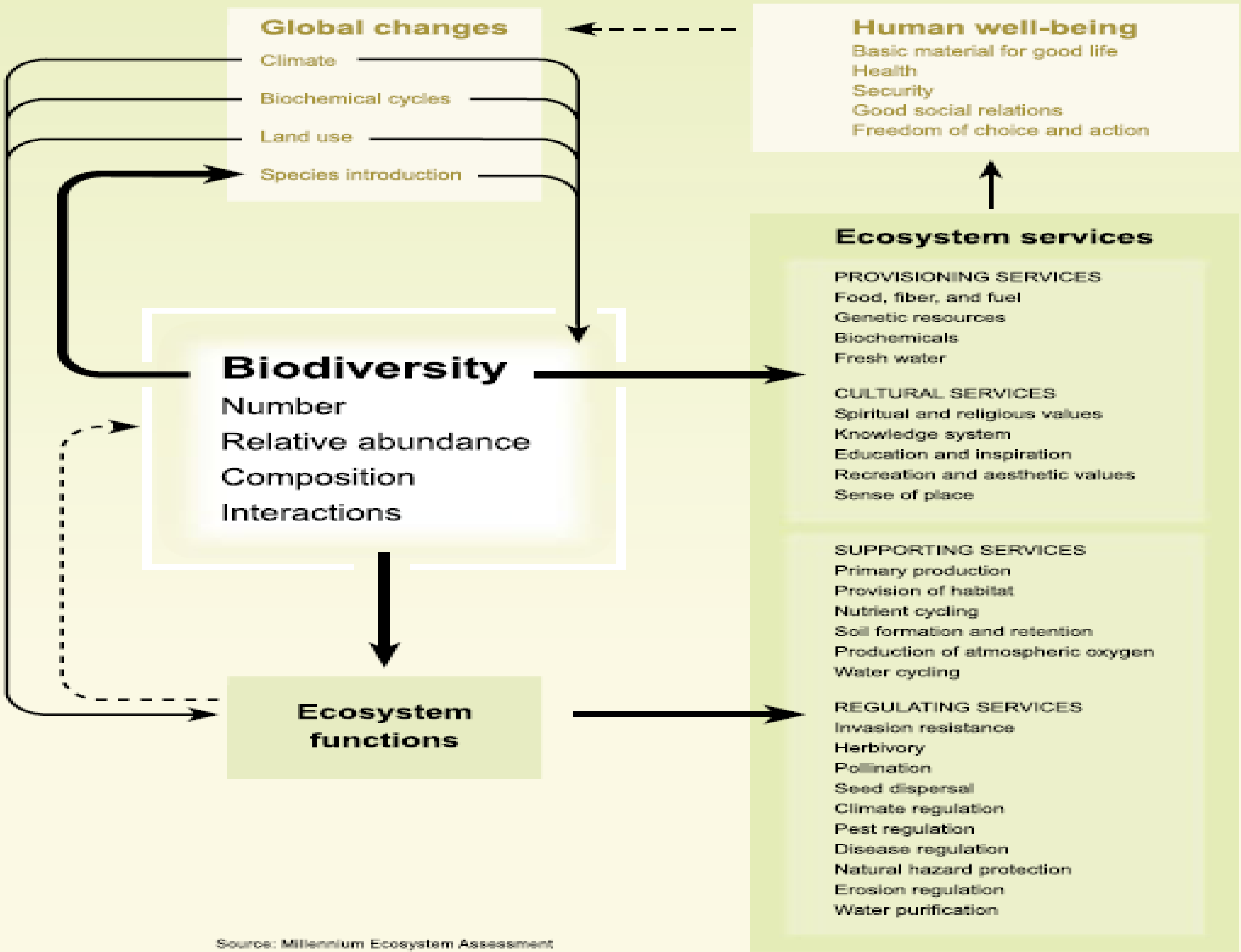
Agronomy: Need for a shift from Agrochemistry to Agroecology

Setting up an **ecologically intensive** agriculture is now a major objective for providing more and better food to populations of both the southern and northern hemispheres

The paradigm of **ecological intensification** is based on **the optimization of biological interactions and regulations in agroecosystems**

- How to implement ecological intensification ?
  - Which mecanisms ? Which systems ?

- How to set/promote innovation processes based on ecological intensification ? ?


Global changes
Climate
Biochemical cycles
Land use
Species introduction
Human well-being
Basic material for good life
Health
Security
Good social relations
Freedom of choice and action
Ecosystem services
PROVISIONING SERVICES
Food, fiber, and fuel
Genetic resources
Biochemicals
Fresh water
CULTURAL SERVICES
Spiritual and religious values
Knowledge system
Education and inspiration
Recreation and aesthetic values
Sense of place
SUPPORTING SERVICES
Primary production
Provision of habitat
Nutrient cycling
Soil formation and retention
Production of atmospheric oxygen
Water cycling
REGULATING SERVICES
Invasion resistance
Herbivory
Pollination
Seed dispersal
Climate regulation
Pest regulation
Disease regulation
Natural hazard protection
Erosion regulation
Water purification
Biodiversity
Number
Relative abundance
Composition
Interactions
Ecosystem functions
Source: Millennium Ecosystem Assessment

Which trade-offs between productivity and biodiversity ?

Production loss ?

Biodiversity loss ?

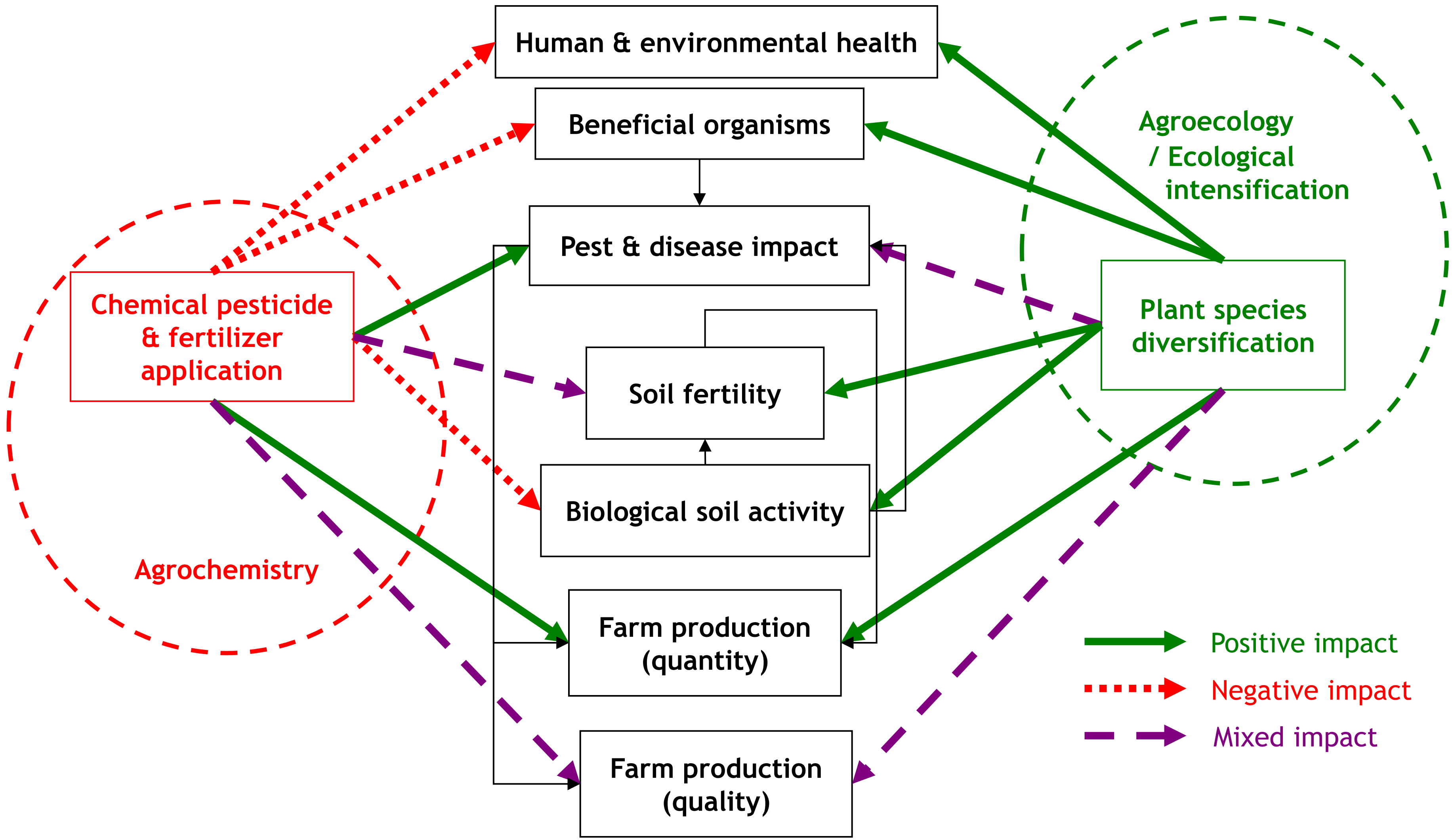
Main Hypothesis

- It is possible
- To increase production in quantity and quality
- To decrease the dependancy to chemicals
- To get a better control of bioagressors and a better management of natural resources

- **By increasing biological diversity** in cropping systems (plant associations, rotations, service plants, landscape organization, etc.)

- **By optimizing biological interactions** in cropping systems

Vegetal diversification: the main pillar of ecological intensification

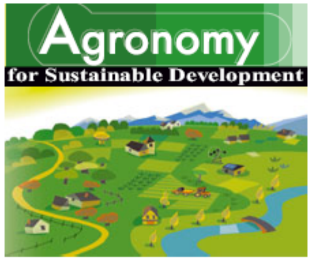


How to implement ecological intensification ?

Agron. Sustain. Dev. 29 (2009) 43–62

DOI: 10.1051/agro:2007057

Available online at:
www.agronomy-journal.org



Review article

Mixing plant species in cropping systems: concepts, tools and models. A review

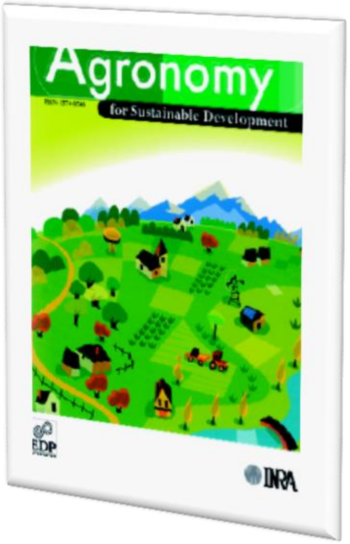
E. Malézieux[1*], Y. Crozat[2], C. Dupraz[3], M. Laurans[4], D. Makowski[5], H. Ozier-Lafontaine[6], B. Rapidel[1,7], S. de Tourdonnet[5], M. Valantin-Morison[5]

Agronomy Sust. Developm.
DOI 10.1007/s13593-011-0022-4

REVIEW ARTICLE

Plant species diversity for sustainable management of crop pests and diseases in agroecosystems: a review

Alain Ratnadass · Paula Fernandes · Jacques Avelino · Robert Habib



A radical change of perspective

- Hypothesis: stability of complex systems
- Using complementary functional attributes in terms of resource captation
- Favour positive interactions
- Optimize food networks

Natural ecosystems vs. agroecosystems

- Specific diversity
- Spatial heterogeneity, numerous interfaces
- Perennial cover
- Functional redonduncies
- Presence of trees

Lefroy E.C., Hobbs R.J., O'Connor M.H. and J.S. Pate (editors), 1999
Agroforestry Systems Volume 45, 446p
Agriculture as a mimic of natural Ecosystems.

Wes Jackson, AEE 88 (2002) 111–117
Natural systems agriculture: a truly radical alternative

Towards a mimic of natural ecosystems ?

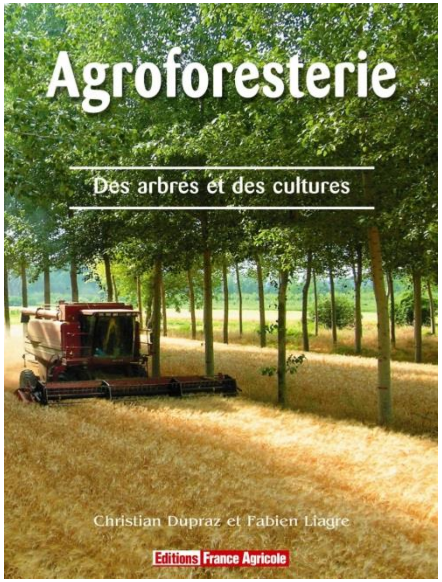
Agronomy Sust. Developm.
DOI 10.1007/s13593-011-0027-z

REVIEW ARTICLE

Designing cropping systems from nature

Eric Malézieux

More complex systems



Number of cultivated species

Various forms to incorporate specific diversity at the field scale

Space

Gradient of interactions

Time

- Plant associations (mixed cropping, agroforestry, cover crops)
- Relay cropping
- Rotations

Mixing plants with production objectives

(Re)introducing trees in the fields

Introducing service plants in monocrop systems

Introducing covercrops in annual cropping systems

Mixing to control bioagressors

Agronomy Sust. Developm.
DOI 10.1007/s13593-011-0022-4

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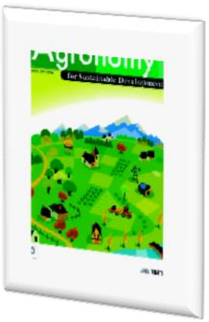
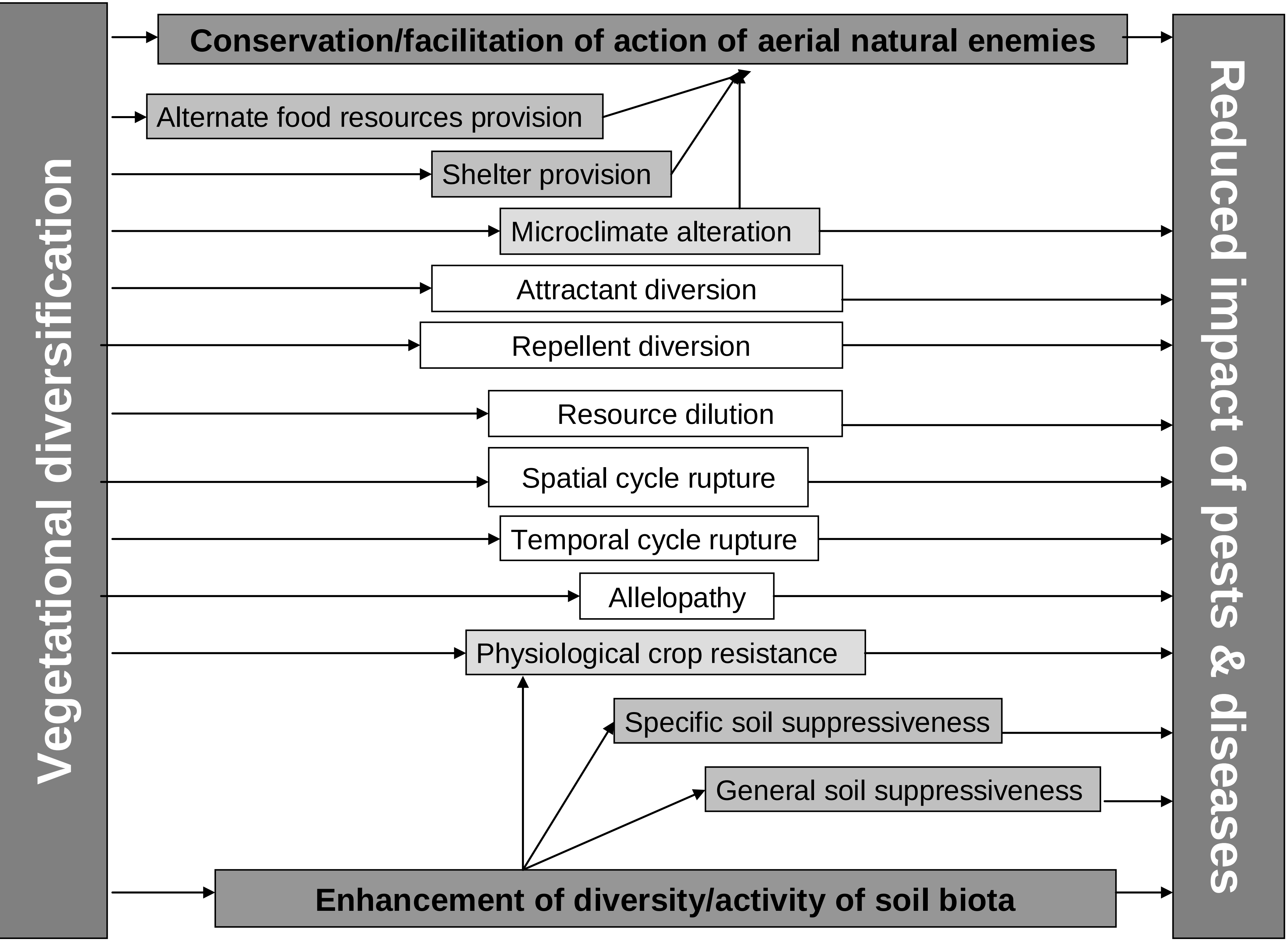
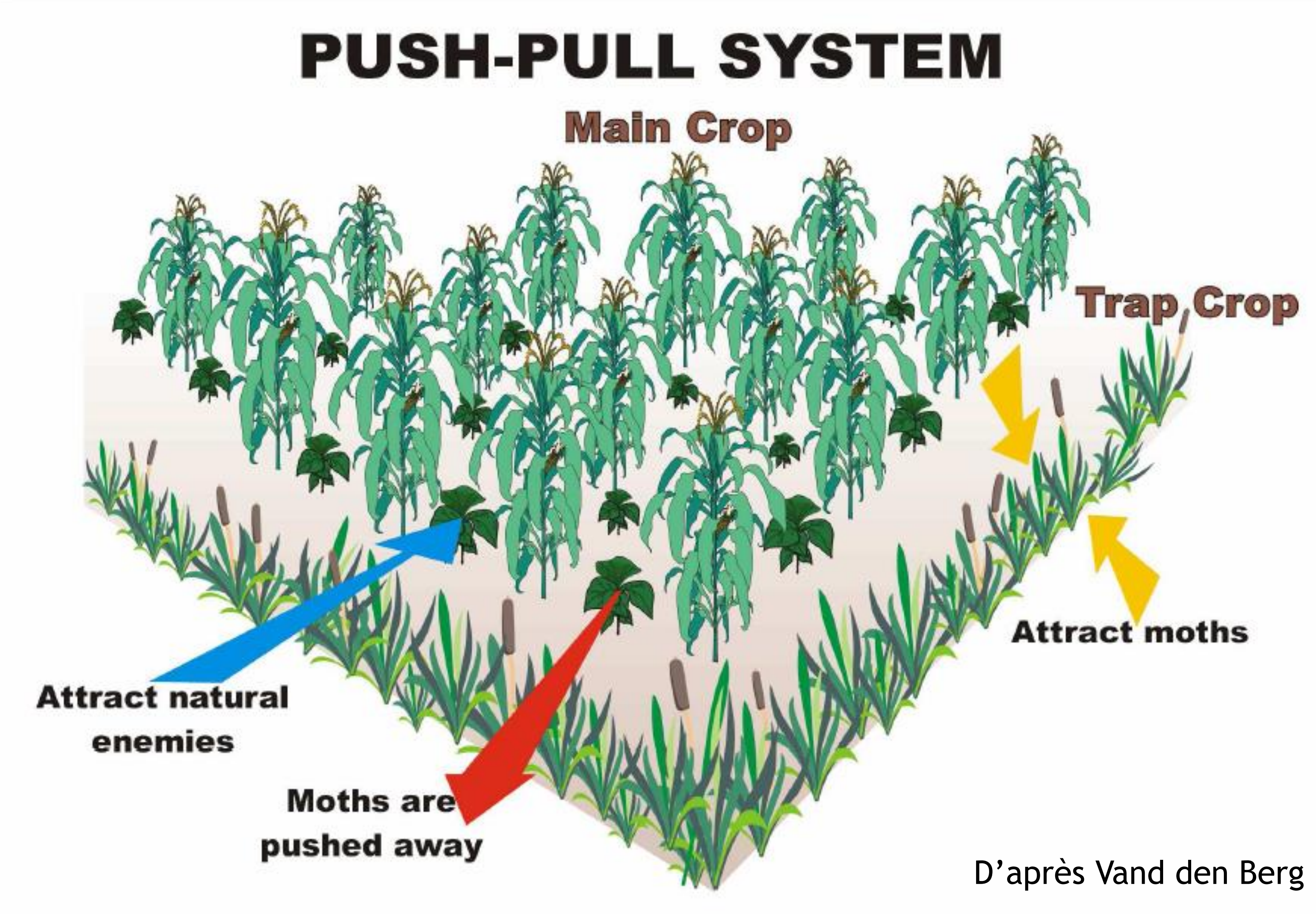


Accepted: 11 December 2010


Vegetational diversification
Conservation/facilitation of action of aerial natural enemies
Alternate food resources provision
Shelter provision
Microclimate alteration
Attractant diversion
Repellent diversion
Resource dilution
Spatial cycle rupture
Temporal cycle rupture
Allelopathy
Physiological crop resistance
Specific soil suppressiveness
General soil suppressiveness
Enhancement of diversity/activity of soil biota
Reduced impact of pests & diseases



D'après Vand den Berg

(from A. Ratnadass)

Evaluation of trap crops for the regulation of gombo and sorgho bioagressors (Icrisat-Cirad/ Inran/ UAM, station Inran Birni N'Konni, 2008)

Trap crops to control tomato pest *Helicoverpa zea*
B. Rhino (Cirad)

(from A. Ratnadass)

Mixing for ressource use efficiency

Water

Agronomie 24 (2004) 383–395
© INRA, EDP Sciences, 2004
DOI: 10.1051/agro:2004029

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Original article

Modelling crop residue mulching effects on water use and production of maize under semi-arid and humid tropical conditions

Eric SCOPEL[a], Fernando A.M. DA SILVA[b], Marc CORBEELS[a]*, François AFFHOLDER[a], Florent MARAUX[c]

Carbon

Global Change Biology (2006) 12, 1–15, doi: 10.1111/j.1365-2486.2006.01233.x

Soil carbon storage potential of direct seeding mulch-based cropping systems in the Cerrados of Brazil

MARC CORBEELS*†, ERIC SCOPEL*†, ALEXANDRE CARDOSO†, MARTIAL BERNOUX‡, JEAN-MARIE DOUZET§ and MARCOS SIQUEIRA NETO¶

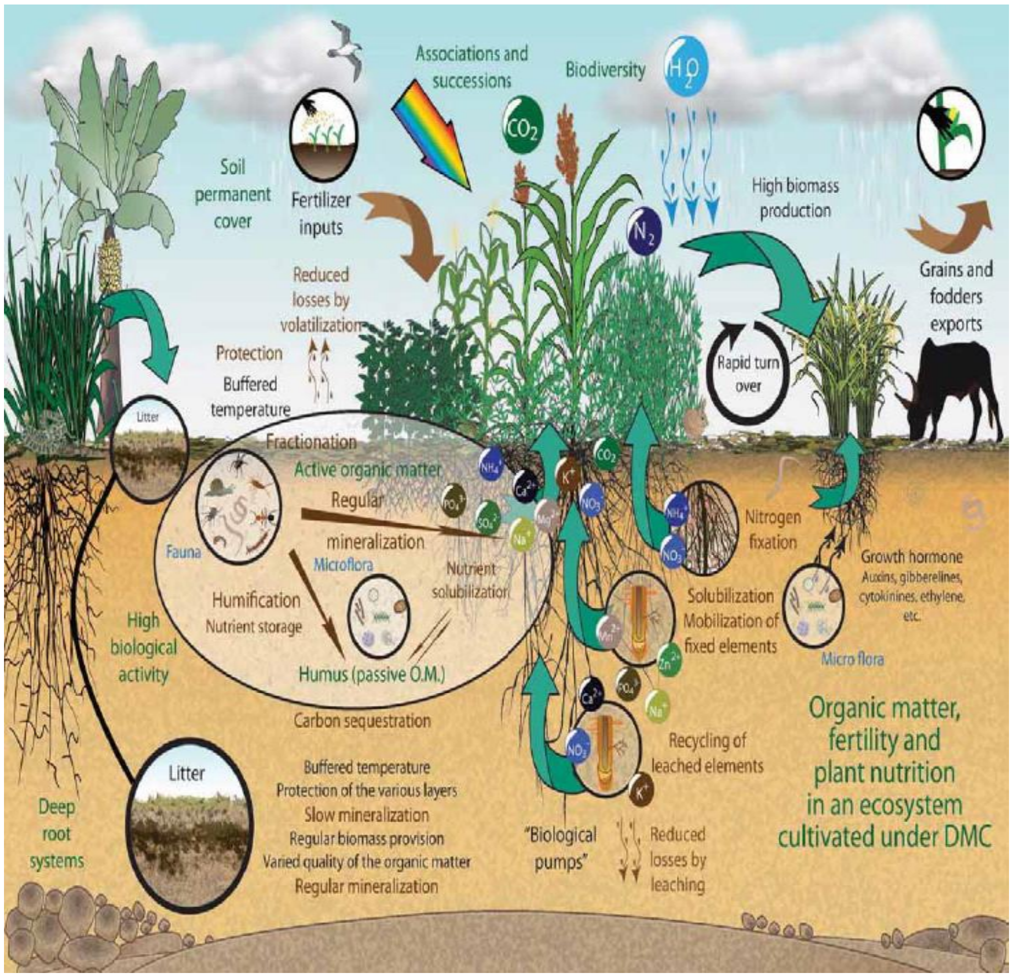
Nitrogen

Cover Crop and Nitrogen Effects on Maize Productivity in No-Tillage Systems of the Brazilian Cerrados

A. Maltas, M. Corbeels,* E. Scopel, J. Wery, and F. A. Macena da Silva

AGRONOMY JOURNAL since 1908

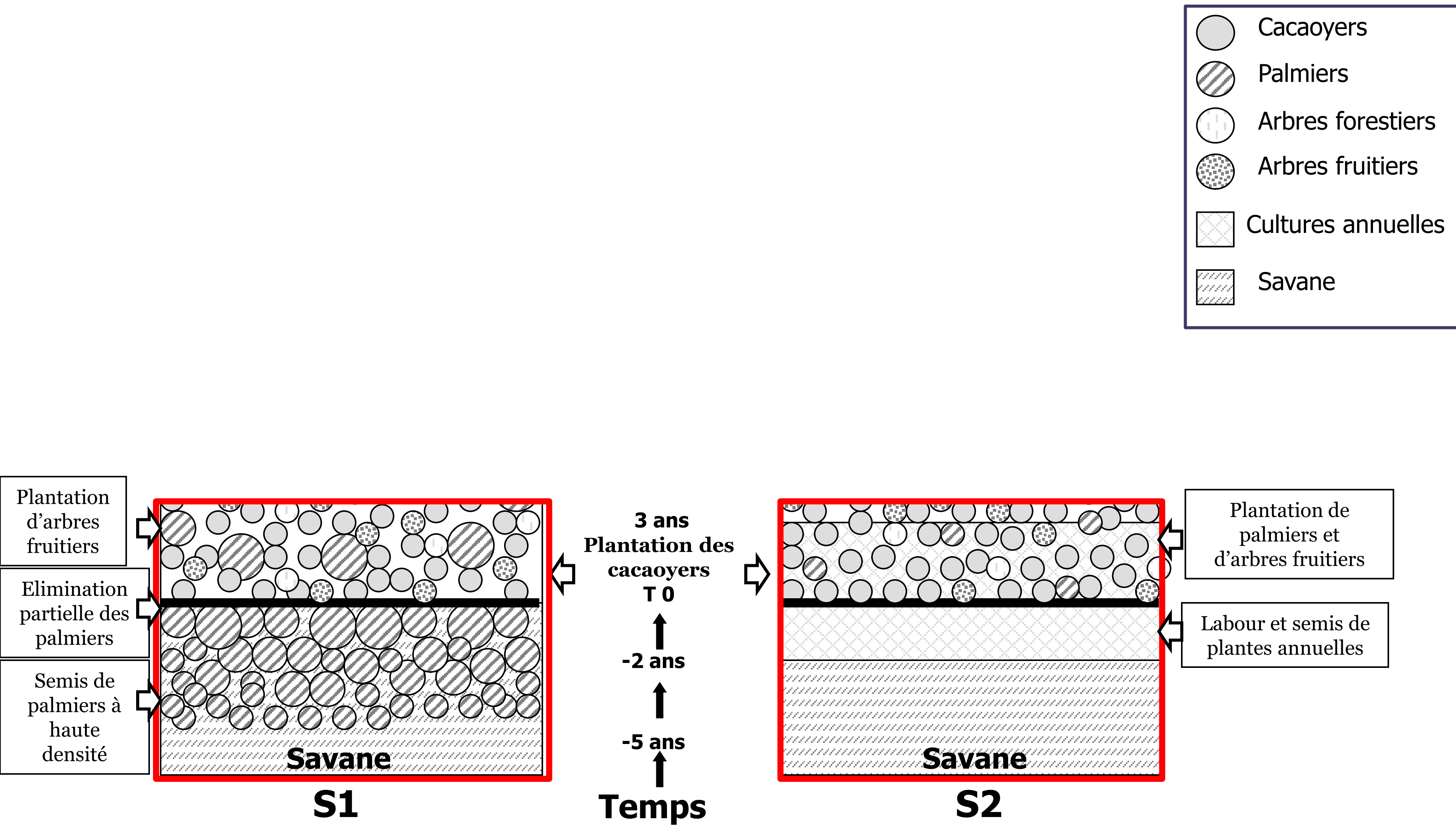
Specific role of cover crops for an integrated fertility management



- Controling erosion
- Biological N fixation
- Recycling nutrients
- Increasing SOM stocks
- Stimulating biological activity

How to set / promote innovation processes based on ecological intensification ?

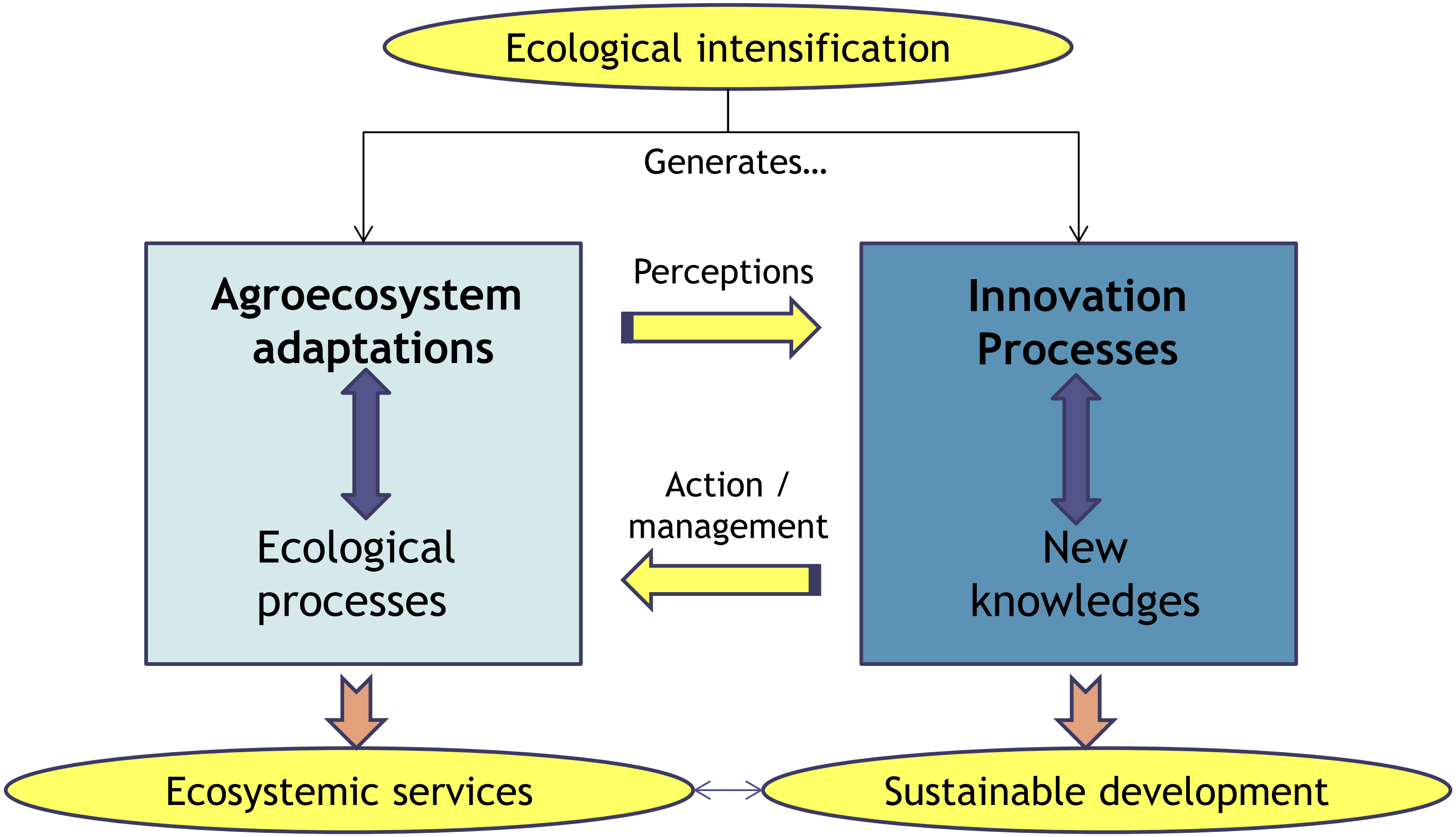
From savannahs to agroforests (from Jagoret, 2010)



Main challenges for family farming :

- Agroecological systems **are complex and knowledge intensive**
- They often require **a transition phase** before reaching a new beneficial equilibrium (long term investment)
- Family farmers need to be **convinced**, **to be able to innovate** and **to face risks** linked with changes
- Technical changes have to fit with their own resources and with the dynamics of family farms in their context
- Family farmers need to organize themselves to exchange experiences, to negotiate with private sector, markets or policy makers

Relation between ecological changes and innovation processes



Source: adapted from Pepites project conceptual framework

Design Strategy

APPROACH

Global

Systemic

Integrative

Multicriteria

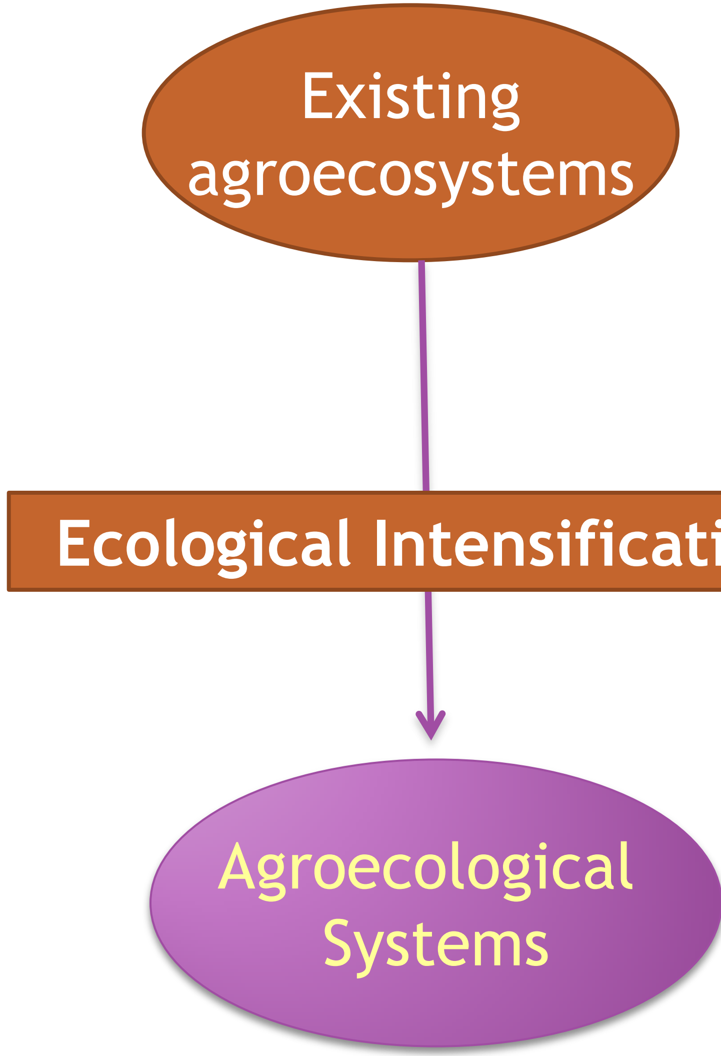
Participative

SCALES

Plot

Farm

Landscape



NEEDS

Biological diversity

Scientific knowledge

Knowledge in Functional ecology & agronomy

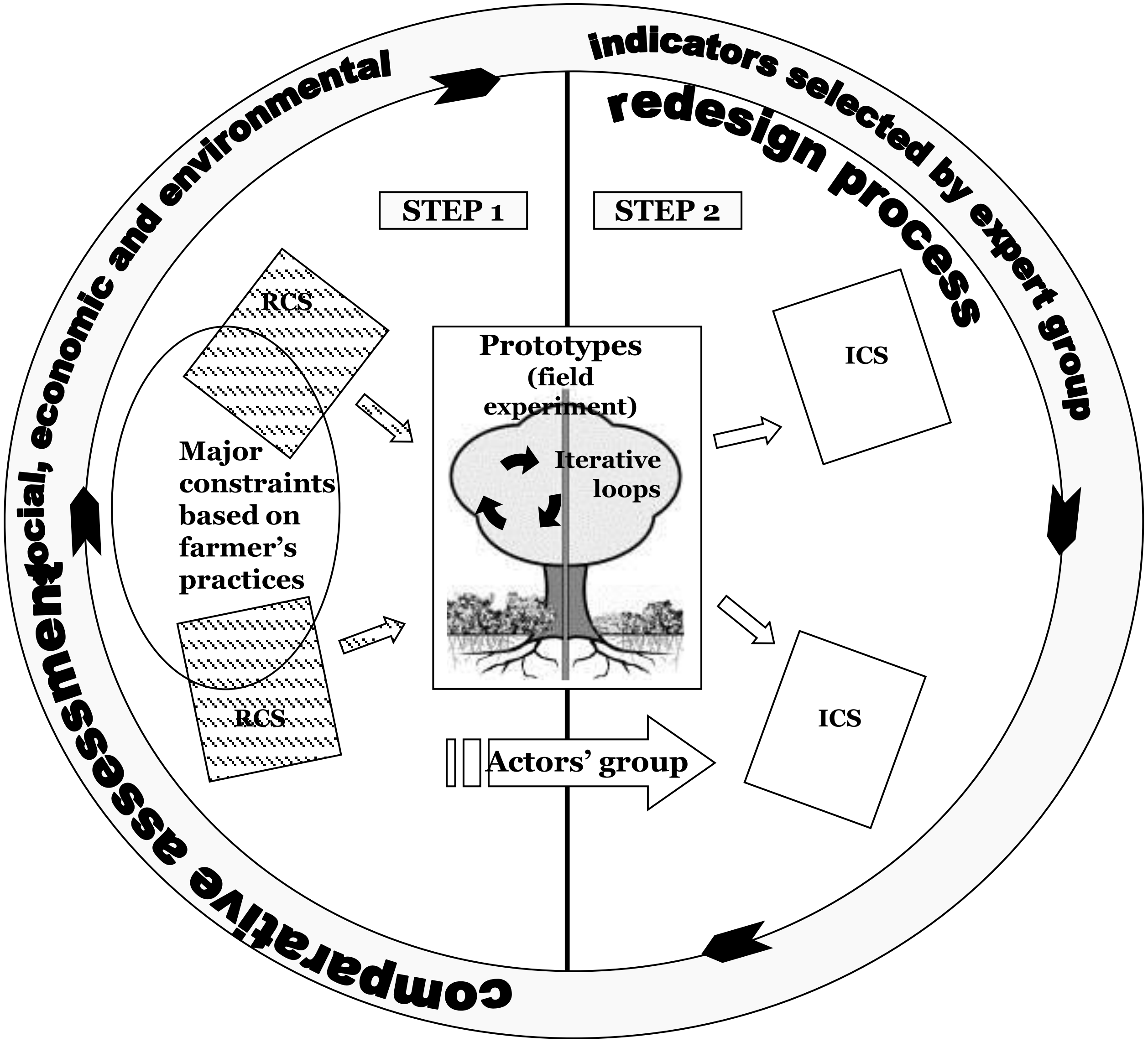
Local knowledge

The development of AE systems needs to be progressive and participatory

Farmers should be direct
protagonists of the
EI systems development

Farmers should have
the opportunity to share their
own experience

Participatory method to redesign and to assess innovative sustainable cropping systems - F. LeBellec, HortSys



Step 1 = building up and evaluating cropping system prototypes, based on farmer's practices.

Step 2 = validating the prototypes in a network of experimental farms.

Redesign process: ICS becomes RCS and follows the same improvement process as for step 1.

RCS: Reference cropping system, ICS: innovative cropping system, Actor group composed of farmers

Developing Low-Cost Pest Exclusion and Microclimate Modification Technologies For small-scale Growers in Kenya and Benin

www.bionetagro.org

Contact: tmartin@icipe.org

HortCRSP

USAID
FROM THE AMERICAN PEOPLE

KARI

A TO Z

MICHIGAN STATE UNIVERSITY

PRETECTA

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African Insect Science for Food and Health

How the technology works?

- *Direct Effect*
  - *Pest exclusion: The net serves as a physical barrier to insect infestation*
  - *Micro-climate modification: The nets improve temperature, light, relative humidity and soil moisture.*

- *Indirect effects*
  - *Disease control: Low incidence of viral diseases transmitted by insects*

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Rational the technology

- Nets are safe for human health and the environment
- Nets can be combine with biological control method
- Net reduces from 70 to 90% the use of insecticide
- Net improve yield and quality

- Industries like “A to Z” Textile Mills can produce the nets locally
- Nets could be used for 3 to 5 years in agriculture (low cost)
- Nets are easy to recycle

Malaria bed net production in Tanzania by “A to Z” Textile Mills Ltd

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What we have studied

Agronomical studies

Plants
Insects and mites
Plant physiologie
Microclimate modification
Plante disease
Quality of production
Timework
Watering

Socio- economic studies

Transfer to small holder farmers
Adoption process
Condition for adoption
Economical interest
Environmental interest
Public health interest

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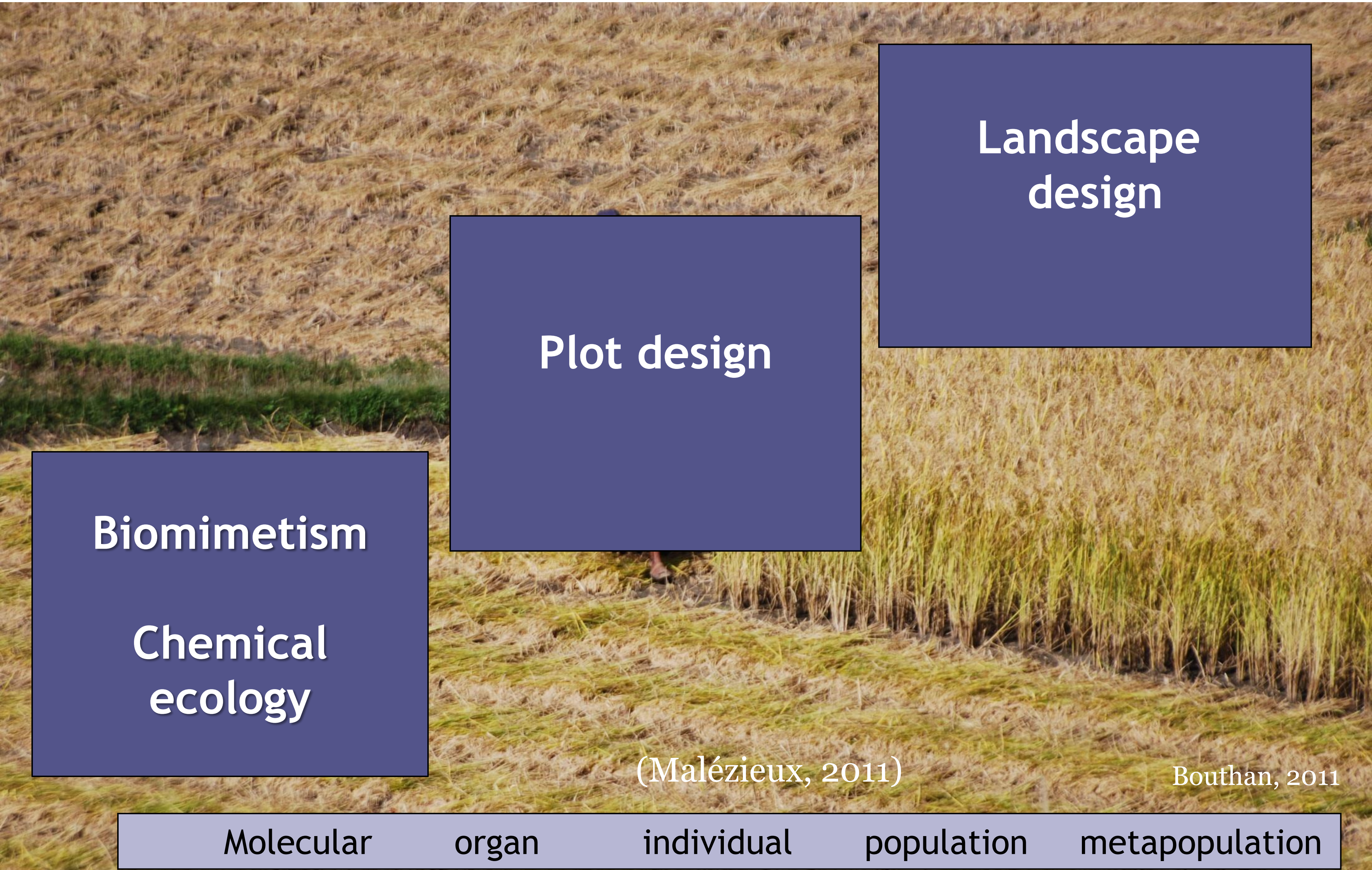
At which scale ?



Conclusion : which Challenges for research?

- Global approaches and methods:
  - Develop systemic approach & framework
  - Develop participatory approaches and methods for co-conception and diffusion of AE innovations
- Plot and landscape level : Agroecological functioning of cropping systems
  - Optimize below and over ground regulations (competition, facilitation, predation, allelopathy)
  - Cropping system design and technical management
- Farm level
  - Resource allocation and labour organization
- Institutional & policy issues, education and training:
  - How can policies favour AE innovation and transition ?

Thank You
for your attention…